BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Gravity-Gradient Momentum Dumping for a CM-SM/LM-ATM Mission

Case 620

DATE: September 6, 1968

FROM: W. Levidow

ABSTRACT

A single rotation, two maneuver gravity-gradient dump procedure can be used to dump the CMG momentum produced by gravity torque. Maneuvering is done only during orbital darkness to maximize the solar viewing time.

For small values of β, all the momentum accumulated during solar viewing can be dumped during orbital darkness. For larger values of β, reaction thrust is needed to supplement gravity-gradient dumping in order to prevent CMG saturation.

Gravity-gradient dumping reduces the reaction thrust dump propellant requirement for a 28 day, 50° inclination, 230 NM circular orbit from approximately 340 lbs. to 75 lbs.

Aerodynamic torques also produce bias momentum which must be dumped, particularly in elliptical orbits. The magnitude of this effect is now under study as well as whether or not this bias momentum can be gravity gradient dumped.

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MEMORANDUM FOR FILE

Solar viewing by the CM-SM/LM-ATM requires pointing the vehicle out of the orbital plane toward the sun. In this attitude a gravity-gradient bias torque acts along an axis lying in the orbital plane and perpendicular to the long axis of the vehicle. This bias torque produces a unidirectional CMG momentum change which must be periodically dumped before saturation is reached.*

The bias momentum change during any interval of time is proportional to the sine of twice the angle between the orbital plane and the long axis of the vehicle. During solar viewing this is the angle β between the orbital plane and the earth-sun line. If during orbital darkness the vehicle is rotated to a new angle, such that the sine of twice the angle changes sign, the gravity-gradient torque reverses direction and momentum dumping results. Maximum dumping rate occurs when the vehicle makes an angle of 45° with its orbital plane.

Rotating the long axis of the CM-SM/LM-ATM to and from the appropriate dump attitude results in a single-axis, two-maneuver dump procedure.

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* Atmospheric density variations along the orbit also produce a bias torque. For circular orbits, the density variations are due mainly to the diurnal bulge and this results in a small bias torque. For elliptical orbits, extreme density variations due to changes in altitude produce a considerable bias torque (requiring reaction thrust dump propellant possibility in excess of 200 lbs. without gravity gradient dumping). Further study of this effect is required.

For maximum utilization of orbital daylight for solar experiments, dump maneuvers are performed only during orbital darkness. Torque for the maneuver is obtained by controlling the rate of change of the CMG angular momentum vector. This vector can be varied from zero to approximately 6000 ft-lb-sec in any direction by means of gimbal torques on each of the three gyros. Allotting a momentum change of 4500 ft-lb-sec[1] for each maneuver produces a vehicle rotational velocity of 0.6 /sec.* The maximum maneuver angle of 90° requires a maximum maneuver time, including acceleration and deceleration, of 2.5 minutes. Negligible dumping occurs during this maneuver time.

The period of orbital daylight increases as β increases until at some value of β, determined by the orbital height, the orbit lies completely in daylight. Hence an increase in β results in a decrease in the period of orbital darkness and thus a decrease in the dump capability.

For small values of β, all of the momentum accumulated during solar viewing can be gravity-gradient dumped during orbital darkness. For large values of β, the momentum accumulated during solar viewing exceeds the dump capability. The excess can be dumped before the accumulation reaches saturation by means of a reaction thrust torque. Reaction thrust dumping may be scheduled once per orbit during orbital darkness or less frequently as required.

The dumping characteristic for a 230 NM circular orbit was studied [1] as being representative of the possible CM-SM/LM-ATM missions. The results are shown in the accompanying figure. For $|\beta|<30^\circ$, the dump capability exceeds the momentum accumulated during solar viewing and no reaction thrust propellant is required. For $|\beta|>30^\circ$, the dump propellant requirement increases to a maximum at $|\beta|=69.6^\circ$, at which time the complete orbit lies in daylight.

The range of β encountered during a mission depends on the launch date, orbit inclination, and mission duration. Hence these factors also determine the total reaction thrust dump propellant required per mission. The following table shows the maximum dump propellant requirements, depending upon launch date, for a 28 day mission with a 50° inclination circular orbit.

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* Moments of Inertia (slug-ft^2) of the CM-SM/LM-ATM are:
Short axis 4.14×10^5 (Dump maneuver rotational axis)
Long axis 1.66×10^5

Orbital Height	Reaction Thrust Dump Propellant, lbs. Without G.G. Dumping	With G.G. Dumping
200 NM	341.5	2.4
300 NM	327.8	33.9
400 NM	312.4	76.5

These propellant savings are representative of the savings expected over the range of orbits examined for the decoupled mission.

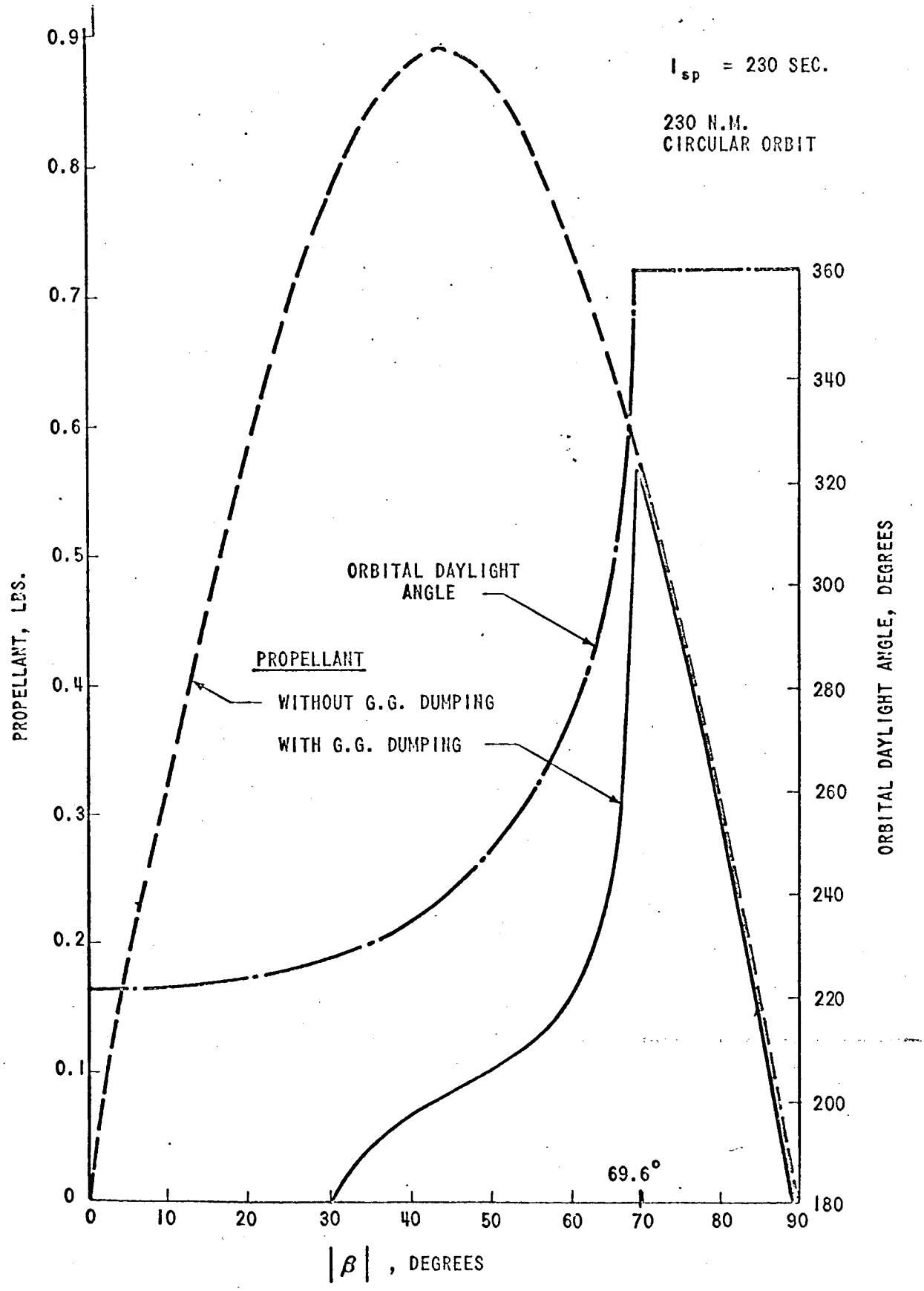
W. Levidow

1022-WL-ms W. Levidow

Attachment.

References

1. Levidow, W., "Single Axis, Two Maneuver Gravity-Gradient Dump Procedure for AAP-ATM Missions," Bellcomm Memorandum for File, in preparation.



REACTION THRUST DUMP PROPELLANT REQUIRED PER ORBIT

BELLCOMM, INC.

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